



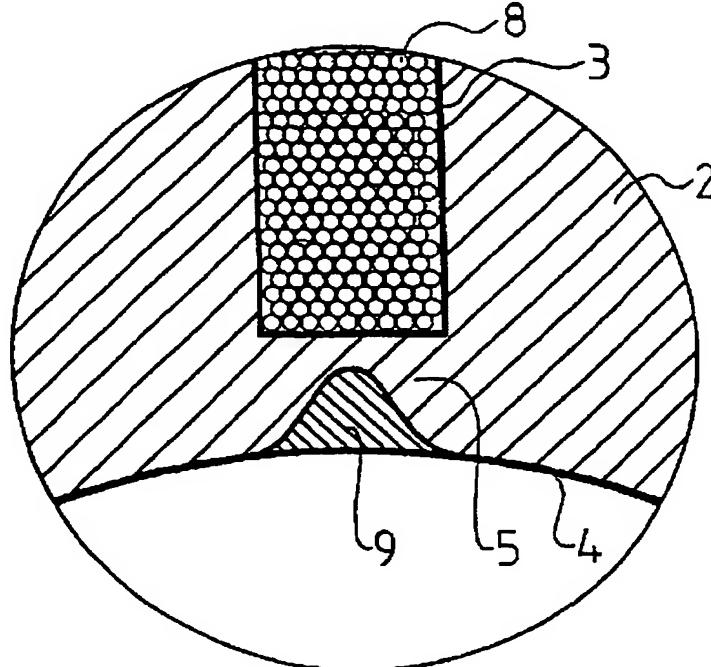
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(54) Title: A STATOR FOR A ROTARY ELECTRIC MACHINE AND A METHOD FOR MANUFACTURING THEREOF

(57) Abstract

A stator for a rotary electric machine including a first stator part (2) essentially in the form of a hollow cylinder with an inner envelope surface (4) and with a plurality of grooves (3), at least partly running in the axial direction of the stator (1), which are intended to receive stator conductors (8), wherein each of the grooves in radial direction is delimited towards the inner envelope surface of the first stator part by a bridge (5). The first stator part (2) includes at least one flux influencing stator portion (9), which is at least partly arranged in at least one of the bridges and has an interior material structure that provides it with a magnetic resistance, which at least in the direction of the circumference of the stator is larger than the magnetic resistance in the radial direction of the stator in those portions of the first stator part which surround said flux influencing portion.



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5 A STATOR FOR A ROTARY ELECTRIC MACHINE AND A METHOD FOR MANUFACTURING THEREOF**THE FIELD OF THE INVENTION**

- 10 The present invention refers to a stator for a rotary electric machine including a first stator part essentially in the form of a hollow cylinder with an inner envelope surface and with a plurality of grooves at least partly running in the axial direction of the stator, which are intended to receive stator conductors,
- 15 wherein each of the grooves in radial direction is delimited towards the inner envelope surface of the first stator part by a bridge.

PRIOR ART

- 20 By a rotary electric machine is meant a direct as well as an alternating current machine, and furthermore a synchronous as well as an asynchronous machine. The rotary electric machine is especially suited to be utilised as a motor, but may also be utilised as a generator. In the following, the rotary electric machine will be explained when it is constituted of an asynchronous motor, which in its turn is utilised as an electric motor. This field of application is discussed merely in an exemplifying objective and not in any way in a restricting sense.
- 25
- 30 The stator conductors are intended to be connected to a voltage source. In operation a rotary magnetic flux comes into existence, the speed of rotation of which is settled by inter alia the frequency of the supply voltage. The rotor of the machine is influenced by the rotary magnetic flux and is brought to rotate.
- 35

- In a conventional stator, the grooves for receiving of the stator conductors extend in the axial direction of the stator and are open towards the inner envelope surface of the stator. Consequently, the stator conductors in the form of so called coils are placed in the grooves, in the radial direction, from the inner space of the stator. However, in the stator in question the grooves are arranged at a distance from the inner envelope surface. Thus, each of the grooves is delimited towards the inner envelope surface by said bridge. A plurality of advantages can be achieved by such a stator compared with the conventional stator. For instance, by such a stator, opportunities are created for a substantially smooth circular-cylindrical inner surface of the stator. By suitable design of the rotor, a machine can be accomplished with a substantially uniform gap between the stator and the rotor in the direction of the circumference of the rotor, which is advantageous for the achievement of a high efficiency.
- A stator, in which the stator grooves are separated from the inner envelope surface of the stator, is further advantageous for applications where a gas, which in direct contact with those grooves should have a negative effect on the function of the stator conductors, is intended to be utilised in the gap between the stator and the rotor.
- The stator, in which the stator grooves are open towards an outer envelope surface of the first stator part is also known. By reason of this, the stator conductors can be placed in the grooves from the outside of the first stator part, which is advantageous for reasons of manufacturing technique.
- In order to accomplish a machine with high efficiency, a magnetic flux through the bridges in the direction of the circumference should be minimised. This has according to prior art been achieved by the fact that the grooves are arranged in such a way that a bottom of respective groove is located in

close vicinity to the inner envelope surface of the stator. However, it has turned out, especially when the grooves extend relatively far in the radial direction of the stator, that a too thin bridge has a tendency to be deformed and may be ruptured
5 during manufacturing and handling of the stator.

SUMMARY OF THE INVENTION

An object of the invention is to provide a stator for a rotary
10 electric machine, which presents bridges that separate respective stator grooves from an inner envelope surface of the stator, and which stator provides the conditions for the achievement of a machine, which in relation to previously known machines presents a high efficiency in combination with a
15 relatively high mechanical rigidity of the stator.

This object is achieved in that the first stator part includes at least one flux influencing stator portion, which is at least partly arranged in at least one of the bridges and has an interior
20 material structure that provides it with a magnetic resistance, which at least in the direction of the circumference of the stator is larger than the magnetic resistance in the radial direction of the stator in those portions of the first stator part which surround said flux influencing portion. Since the stator portion is arranged
25 in the bridge, occurrence of an undesired stray flux through the bridge in the direction of the circumference of the stator is counteracted in the operation of the machine and the magnetic flux is thus forced to run in the radial direction of the stator to a great extent. This, in its turn, results in a high concentration of
30 the magnetic flux in the gap between the stator and the rotor, resulting in a high efficiency of the machine.

According to an embodiment of the invention, a plurality of said flux influencing portions are arranged mutually spaced in the direction of the circumference of the stator between the grooves
35 and said inner envelope surface. Hereby, the magnetic flux is

directed to run in the first place in radial direction between the flux influencing portions, which results in an enhanced efficiency.

- 5 According to a further embodiment of the invention, in the direction of the circumference of a stator, the stator portion has substantially the same extension as one of said bridges. Hereby, the presence of the stator portion will substantially not have any negative effects on the magnetic flux in the radial direction of
10 the stator.

According to a further embodiment of the invention, the interior material structure in the flux influencing portion provides the latter with a lower permeability than the permeability of those
15 parts of the first stator part which surround the flux influencing portion. Hereby, the flux influencing portion is saturation-magnetised at an, in relation to the rest of the first stator part, lower magnetic flux. This implies that the bridge is saturation-magnetised at a lower magnetic flux in relation to prior art,
20 which in its turn leads to the magnetic flux to a greater extent running in the radial direction.

According to a further embodiment of the invention, the interior material structure in the flux influencing portion presents such a
25 magnetic domain structure that a magnetic flux through the flux influencing portion in the direction of the circumference of the stator is counteracted. The magnetic domains are for instance arranged with a low mutual mobility. Hereby, the magnetic flux is forced to run to a great extent in the radial direction of the
30 stator.

According to a further embodiment of the invention, the flux influencing portion extends over at least 50% of the radial extension of the bridge. Hereby, merely very small magnetic flux
35 will run in the direction of the circumference of the stator through the bridges, which provides a high efficiency.

A further object of the invention is to provide a method for manufacturing of a stator for a rotary electric machine, by means of which the stator can be manufactured with a relatively

- 5 high mechanical rigidity and which stator furthermore provides the conditions for the accomplishment of a machine with a high efficiency.

This object is achieved in that a first stator part is manufactured
10 essentially in the form of a hollow cylinder with an inner envelope surface and with a plurality of grooves at least partly running in the axial direction of the stator, each of which is delimited towards the inner envelope surface of the first stator part by a bridge and which are intended to receive stator
15 conductors, and in that at least one stator portion, which at least partly is formed by at least one part of one of said bridges, is treated in such a way that it obtains an interior material structure that provides it with a magnetic resistance, which at least in the direction of the circumference of the stator is larger
20 than the magnetic resistance in the radial direction of the stator in those portions of the first stator part which surrounds said stator portion. A magnetic flux, generated by the machine in operation, will thus run to a less degree in the direction of the circumference of the stator through the bridges and to a higher
25 degree in the radial direction of the stator to the air gap, located between the stator and the rotor, and to the rotor, which results in an enhanced efficiency of the machine.

According to a further embodiment of the invention, each stator
30 portion is treated in such a way that it obtains an interior material structure with a substantially lower permeability than the permeability in those parts of the first stator part which surrounds the stator portion. In operation of the machine, the bridges including the first portions will thus be saturation-magnetised at a reduced magnetic flux. This results in the
35

magnetic flux to a higher degree extending in the radial direction of the stator.

According to a further embodiment of the invention, each stator portion is treated in such a way that it obtains an interior material structure with a larger magnetic resistance in the direction of the circumference of the stator than in the radial direction of the stator. Thus, the magnetic characteristics will after the treatment be directed in such a way that a magnetic flux through the stator portion in the direction of the circumference of the stator is counteracted.

According to a further embodiment of the invention, each stator portion is tooled in such a way that the stator portion is plastically deformed. Such a tooling is relatively easy to accomplish and therefore the cost will be moderate. The tooling may for instance be done by means of a substantially cylinder-shaped tool, with an outside diameter which is somewhat smaller than the inside diameter of the stator, and by a number of portions protruding from the cylindrical surface, wherein the tool is lead through the inner space of the stator. Consequently, the protruding portions are intended to at least partly deform the bridges in such a way that the magnetic domains are affected.

Further embodiments of the stator and the method for manufacturing thereof according to the invention will more closely be seen in the claims and in the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of the preferred embodiments of the invention with reference to the drawings attached, described by way of example, follows below.

Fig 1 discloses a cross-section view of a stator according to a first preferred embodiment.

Fig 2 discloses the design of the stator more closely for one of the grooves of the stator, illustrated in Fig 1.

5 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS
OF THE INVENTION

Fig 1 discloses a stator 1 essentially in the form of a hollow cylinder according to a first preferred embodiment. The stator 1 includes a first part 2 with a number of grooves 3 running in its axial direction. Each of the grooves 3 is delimited in radial direction towards an inner envelope surface 4 of the first stator part by a bridge 5. The bridge 5 forms a part of the first stator part 2. Thus, the bridges 5 and the portions of the first stator part, which are located between the grooves 3, form a continuous part. A plurality of stator conductors 8 are arranged in the grooves 3, so called coils in the form of a plurality of fine wires all of electrically well conductive material such as copper. Since the grooves 3 are open towards an outer envelope surface 6 of the first stator part 2, the stator conductors can easily and effectively be positioned in the grooves 3.

25 A second stator part 7 is arranged in radial direction outside the first stator part 2 and encloses it. A rotor is intended to be arranged inside the inner envelope surface 4 of the stator. An air gap is arranged between the stator 1 and the rotor.

30 The stator will below be explained for the case when it constitutes a part of a rotary electric machine in the form of an electric motor. The stator conductors 8, arranged in the grooves 3, are connected to a voltage source. When the stator conductors 8 are supplied in a suitable way, a magnetic flux comes into existence in the machine, which runs through a magnetic circuit that is formed by the first stator part 2, the 35 rotor, and the second stator part 7. The magnetic flux is intended to pass the air gap between the stator 1 and the rotor

in radial direction. In a stator, according to prior art, with said bridges 5 between the grooves 3 and the inner envelope surface 4 of the stator, there is a risk that a part of the flux runs through the bridges in the direction of the circumference of the stator,
5 which result in a minor part of the flux passing the air gap and running through the rotor, which in its turn result in a reduced efficiency. By, according to the invention, at least partly restrain the magnetic flux from running in the direction of the circumference of the stator through the bridges, an enhanced
10 efficiency can be obtained. That can be realized in a number of different ways. Some of such ways are described below with reference to both Fig 1 and Fig 2. By arranging a stator portion 9, which at least partly is arranged in a bridge 5, with such an interior material structure that a magnetic flux is influenced in
15 such a way that it at least partly is restrained from running through it, and thanks to the fact that the bridge at load of the machine within the intended load range of the machine is saturation-magnetised, a reduced magnetic flux will run through the bridge and thus the flux is restrained to a higher degree to
20 run in the radial direction of the stator to the air gap and the rotor.

The flux influencing stator portion 9 has reduced magnetic characteristics relatively the surrounding stator material. Such
25 stator portions 9 are accomplished preferably by a treatment of the first stator part 2 from its inside. The stator portion 9 extends from the inner surface 4 of the first stator part 2 over at least 50% of the height of the bridge 5 in the radial direction of the stator, preferably over at least 75% of the height of the bridge 5 in the radial direction of the stator and according to a preferred example over at least 90% of the height of the bridge 5 in the radial direction of the stator. The extension of the stator portion 9 in the direction of the circumference of the stator is substantially shorter than the distance between two adjacent
30 bridges 5 in the direction of the circumference of the stator. The extension of the stator portion 9 in the direction of the

circumference of the stator is, according to a preferred embodiment, less than 20% of the distance between the adjacent bridges. Preferably the stator portion 9 presents an extension in the direction of the circumference of the stator, 5 which substantially corresponds to the length of the bridge 5 in said direction of the circumference. The extension of the stator portion 9 in the direction of the circumference of the stator is thus up to at least 90% of the length of the bridge in the direction of the circumference and at a maximum to an 10 extension which is 10% longer than the length of the bridge. In such a way the stator portion 9 will substantially not have any negative effect on the magnetic flux in the radial direction of the stator. The stator portion 9 is according to a preferred embodiment symmetrically arranged in the bridge 5 in the 15 direction of the circumference.

Thus, the object of the stator portion 9 is to provide an enhanced magnetic resistance against magnetic flux in a circuit which extends through that bridge 5 in which the stator portion 9 20 is arranged. Preferably, the stator portions 9 are arranged in each of said bridges 5. The stator 1 is, except for the stator portions 9, essentially formed of a magnetic core. The magnetic core is preferably constituted of iron or an iron alloy. The stator core is according to Fig 1 formed by a first 2 and a second 7 25 stator part.

According to a first example the stator portion 9 has such an interior material structure that the permeability is lower in that portion than in those parts of the first stator part which surround 30 the stator portion 9. Of course, by permeability is here meant magnetic permeability. Such a lower permeability can be achieved by a different material composition or crystal structure relatively the surrounding stator material. Such a lower permeability can for instance be achieved by heat treating of the 35 material. The heat treatment is locally applied on said stator portions. Such a heat treatment can for instance be in the form

of laser exposure. By heating to a suitable level of temperature and thereafter rapid cooling, a desired crystal structure can be achieved in the material. An example on a structure constituent part, which presents low permeability to magnetic fields and
5 which can be achieved by the heat treatment, is constituted by martensite. For instance, the heat treatment can also be in the form of an inductive heating or welding. Thus, according to an example of the accomplishment, the material is heat treated in such a way that a martensite structure is obtained in said stator portions.
10

According to a second example, which forms a complement or an alternative to the first example, the magnetic domains in the stator portion are arranged in such a way relatively each other that they are restrained to move relatively each other. This can for instance be accomplished by defects, in the form of dislocation, core boundaries, point defects, etc, being introduced in the lattice structure. Such defects fix the domain boundaries and thus prevent movement or growing of the
15 domains. When a magnetic field is applied, the domains will therefore not be able to be aligned in the direction of the field, which reduces the magnetic characteristics of the stator portion. Such defects can for instance be accomplished by a plastic deformation. At such a plastic deformation of the bridges can for
20 instance a tool, with a cylindrical shape and with a plurality of portions which are protruding from the tool in its radial direction, be utilised. The deformation is achieved by the tool having such a form that the protruding portions deform the bridges at the positions of said stator portions when the tool is moved through
25 the stator.
30

According to a further example, foreign elements in the form of for instance carbon and nickel are supplied to said stator portion at an enhanced temperature. Hereby, the foreign elements are
35 forced into the lattice and disturb the regularity in it, which has a

negative effect on the magnetic characteristics of the stator portion.

According to a further example, ions in the form of nitrides, 5 carbides, etc. are supplied to the stator portion during the heating. Such ions disturb the regularity in metal lattice and have a reducing effect on the magnetic characteristics of the stator portion.

10 It is also possible to provide said stator portions 9 with an interior structure with aligned magnetic characteristics. In order to counteract a magnetic flux in the direction of the circumference of the stator, the stator portion can be provided with such an interior material structure that it presents a larger 15 magnetic resistance in the direction of the circumference than in the radial direction. Hereby, in the stator portion, conditions are created for obtaining a relatively high maximal magnetic flux density in the radial direction and a relatively low maximal magnetic flux density in the direction of the circumference. This, 20 in its turn, provides the conditions for allowing the stator portion 9 to have a relatively large extension in the direction of the circumference and to extend around the entire inner envelope surface 4 without the efficiency of the machine being negatively affected to a substantial degree. This is advantageous for the 25 achievement of the stator portion 9, since a large part, and up to the whole, of the inner envelope surface 4 can be treated.

It is accentuated that the embodiments described above and 30 illustrated in the drawings merely are to be considered as exemplifying. Consequently, the invention may be realized in other ways, while maintaining of the fundamental idea of the invention. In particular, it is pointed out that persons skilled in this field, after having received knowledge about the solution according to the invention, of course, are capable to perform 35 different re-constructions of the exemplified embodiments without leaving the scope of the patent protection.

The grooves 3 of the stator disclose in the figures a substantially flat bottom faced towards the inner envelope surface 4 of the stator. The bottom of the grooves 3 may be 5 presented in other forms, such as a rounded form, which of course is within the scope of the claims according to the invention.

According to the illustrated embodiment, the stator 1 is 10 constituted of two stator parts. However, it is also possible to design the stator as one piece. In that case the stator conductors have to be led into and through the grooves in the axial direction of the stator.

15 The stator portions 9 may, of course, also be treated by a combination of two or more of the above said treatments.

For instance, the first stator part 2 may be build of a plurality of adjacent plates. These plates are lying in planes which are 20 perpendicular to the axial direction of the stator and form a plate package. The treatment of the stator portions 9 can, of course, within the scope of the claims according to the invention, be done before the assembling of the plates to the plate package as well as after the assembling. The treatment may further be 25 accomplished from the inner surface 4 of the stator as well as from the grooves 3, or from the both directions.

The denote cylinder should be considered in a wide sense and the term cylinder does not necessarily mean that the cylinder 30 has a circle as base surface. However, the base surface may be defined by any closed curve. The stator, disclosed in Fig 1, has the form of a circular cylinder. However, that is only one example of a cylinder within the scope of the invention.

35 The denote bridge is above concerning the portion of the stator which is located in radial direction between each of the grooves

3 and the inner envelope surface 4. The length of the bridge 5 in the direction of circumference of the stator is defined substantially by the width of the groove 3 in the direction of circumference of the stator.

5

It should be noted that the interior material structure in the flux influencing stator portion 9 is different from the interior material structure in those portions of the first stator part which surround the flux influencing portion.

10

It should also be noted that the flux influencing portion advantageously has an interior material structure that provides it with a magnetic resistance which also in other directions than in the direction of the circumference is larger than the magnetic resistance in the radial direction in those stator portions which surround the flux influencing portion. According to a preferred accomplishment, the magnetic resistance in the flux influencing portion is substantially equal in all directions.

15

It should also be noted that those stator portions which surround the flux influencing portion 9 generally have an interior material structure that provides a substantially equal magnetic resistance in all directions.

20

CLAIMS

1. A stator for a rotary electric machine including a first stator part (2) essentially in the form of a hollow cylinder with an inner envelope surface (4) and with a plurality of grooves (3) at least partly running in the axial direction of the stator (1), which are intended to receive stator conductors (8), wherein each of the grooves in radial direction is delimited towards the inner envelope surface of the first stator part by a bridge (5),
5 characterized in that the first stator part (2) includes at least one flux influencing stator portion (9), which is at least partly arranged in at least one of the bridges and has an interior material structure that provides it with a magnetic resistance, which at least in the direction of the circumference of the stator
10 is larger than the magnetic resistance in the radial direction of the stator in those portions of the first stator part which surround said flux influencing portion.
15
2. A stator according to claim 1, characterized in that a plurality of said flux influencing portions (9) are arranged mutually spaced in the direction of the circumference of the stator between the grooves (3) and said inner envelope surface (4).
20
- 25 3. A stator according to claim 2, characterized in that, in the direction of the circumference of the stator, each flux influencing portion (9) has a substantially shorter extension than the distance between two adjacent grooves (3).
- 30 4. A stator according to any one of the preceding claims, characterized in that, in the direction of the circumference of the stator, the stator portion (9) has substantially the same extension as one of said bridges (5).

5. A stator according to any one of the preceding claims, characterized in that the interior material structure in the flux influencing portion (9) provides it with a lower permeability than the permeability of those parts of the first stator part which surround the flux influencing portion.
6. A stator according to any one of the preceding claims, characterized in that the interior material structure in the flux influencing portion (9) provides it with a larger magnetic resistance in the direction of the circumference of the stator than in the radial direction of the stator.
7. A stator according to any one of the preceding claims, characterized in that the interior material structure in the flux influencing portion (9) presents such a magnetic domain structure that a magnetic flux through the flux influencing portion in the direction of the circumference of the stator is counteracted.
- 20 8. A stator according to any one of the preceding claims, characterized in that the flux influencing portion (9) extends over at least 50% of the radial extension of the bridge (5).
- 25 9. A stator according to any one of the preceding claims, characterized in that the bridges (5) and the portions of the first stator part (2), which are located between the grooves, form a continuous part along the direction of the circumference.
- 30 10. A stator according to any one of the preceding claims, characterized in that the first stator part (2) has an outer envelope surface (6) and that the grooves (3) are open towards said envelope surface (6).
- 35 11. A stator according to claim 10, characterized in that the stator includes a second stator part (7), arranged in radial direction outside and enclosing the first stator part (2).

12. A method for manufacturing of a stator to a rotary electric machine, wherein a first stator part (2) is manufactured essentially in the form of a hollow cylinder with an inner envelope surface (4) and with a plurality of grooves (3) at least partly running in the axial direction of the stator, each of which is delimited towards the inner envelope surface (4) of the first stator part (2) by a bridge (5) and which are intended to receive stator conductors (8), characterized in that at least one stator portion (9), which at least partly is formed by at least one part of one of said bridges (5), is treated in such a way that it obtains an interior material structure that provides it with a magnetic resistance, which at least in the direction of the circumference of the stator is larger than the magnetic resistance in the radial direction of the stator in those portions of the first stator part which surround said stator portion (9).
13. A method according to claim 12, characterized in that the treatment is made to a plurality of said stator portions (9), which are mutually separated in the direction of the circumference of the stator and each of them is at least partly formed by solely one of said bridges (5).
14. A method according to claim 12 or 13, characterized in that each stator portion (9) is treated in such a way that it obtains an interior material structure with a substantially lower permeability than the permeability in those parts of the first stator part which surround the stator portion (9).
15. A method according to any one of claims 12-14, characterized in that each stator portion (9) is treated in such a way that it obtains an interior material structure with a larger magnetic resistance in the direction of the circumference of the stator than in the radial direction of the stator.

16. A method according to any one of claims 12-15,
characterized in that each stator portion (9) is heat treated.

17. A method according to claim 16, characterized in that
5 foreign elements are supplied to the metal lattice of each stator
portion (9), respectively, in order to disturb the regularity in it.

18. A method according to any one of claims 12-17,
characterized in that each stator portion (9) is tooled in such a
10 way that the stator portion is plastically deformed.

19. A method according to any one of claims 12-18,
characterized in that each stator portion (9) is treated from the
inner envelope surface (4) of the first stator portion (2).

15 20. A method according to any one of claims 12-19,
characterized in that, in the direction of the circumference of the
stator, each stator portion (9), which is treated, is substantially
delimited by one of said bridges (5), respectively.

20

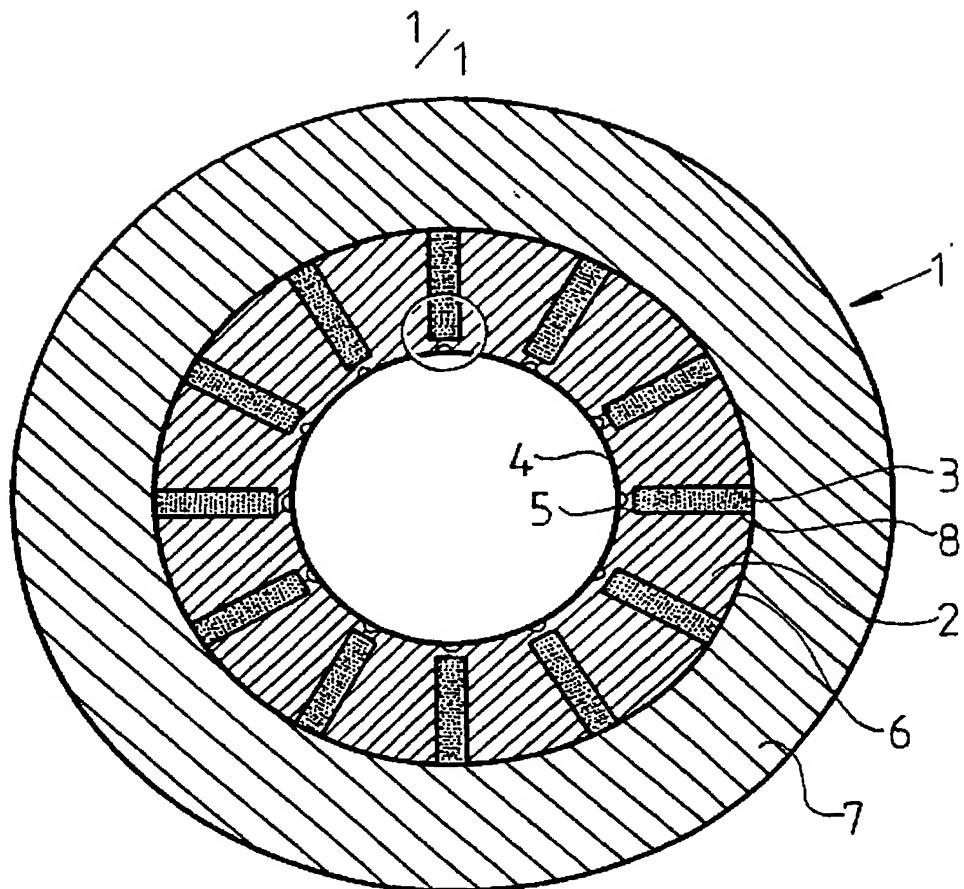


FIG 1

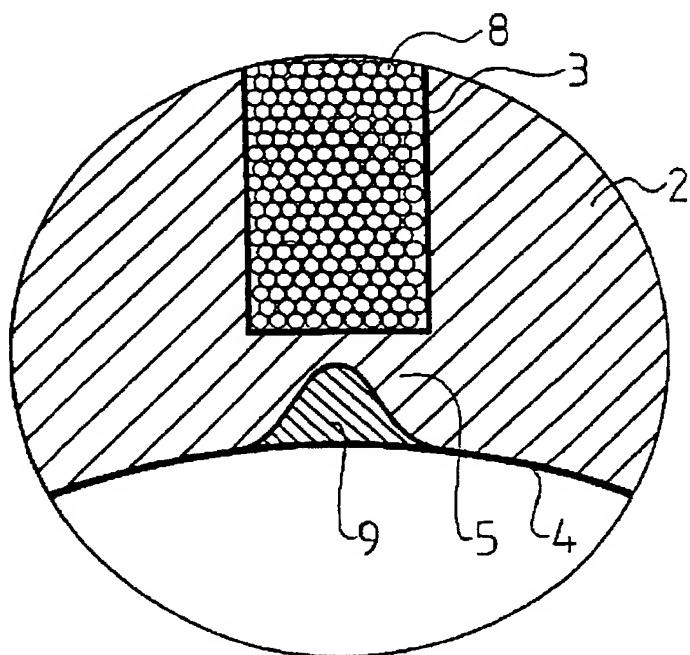


FIG 2

INTERNATIONAL SEARCH REPORT

1

International application No.

PCT/SE 00/00831

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02K 1/16, H02K 15/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, abstract of JP 59-136033 A (SUWA SEIKOSHA KK), 4 December 1984 (04.12.84) --	1-20
A	Patent Abstracts of Japan, abstract of JP 58-190245 A (MATSUSHITA SEIKO KK), 7 February 1984 (07.02.84) --	1-20
A	Patent Abstracts of Japan, abstract of JP 2-211027 A (MATSUSHITA ELECTRIC INC CO LTD), 6 November 1990 (06.11.90) --	1-20

 Further documents are listed in the continuation of Box C. See patent family annex.

- * Special categories of cited documents:
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Date of the actual completion of the international search

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, abstract of JP 60-144121 A (MATSUSHITA DENKI SANGYO KK), 6 December 1985 (06.12.85) -- -----	1-20